Biomimicry—

<http://biomimicry.org/what-is-biomimicry/>

Humans are clever, but without intending to, we have created massive sustainability problems for future generations. Fortunately, solutions to these global challenges are all around us.

**Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature’s time-tested patterns and strategies.**The goal is to create products, processes, and policies—new ways of living—that are well-adapted to life on earth over the long haul.

The core idea is that nature has already solved many of the problems we are grappling with. Animals, plants, and microbes are the consummate engineers. After billions of years of research and development, failures are fossils, and what surrounds us is the secret to survival.

<http://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/copying-mother-nature>

## Copying Mother Nature

Biomimicry looks to nature and natural systems for inspiration. After millions of years of tinkering, Mother Nature has worked out some effective processes. In nature, there is no such thing as waste — anything left over from one animal or plant is food for another species. Inefficiency doesn't last long in nature, and human engineers and designers often look there for solutions to modern problems. Here are seven striking examples of biomimicry. (Text: Shea Gunther)

Read more: <http://www.mnn.com/earth-matters/wilderness-resources/photos/7-amazing-examples-of-biomimicry/copying-mother-nature#ixzz3eBBcjuco>

# [https://upload.wikimedia.org/wikipedia/commons/thumb/e/e2/Klettverschluss.jpg/300px-Klettverschluss.jpg](https://en.wikipedia.org/wiki/File:Klettverschluss.jpg)Biomimetics

From Wikipedia, the free encyclopedia

<https://en.wikipedia.org/wiki/Main_Page>

[Velcro](https://en.wikipedia.org/wiki/Velcro) tape mimics biological examples of multiple hooked structures such as [burs](https://en.wikipedia.org/wiki/Bur).

**Biomimetics** or **biomimicry** is the imitation of the models, systems, and elements of nature for the purpose of solving complex [human](https://en.wikipedia.org/wiki/Human) problems.[[1]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-1) The terms biomimetics and biomimicry come from [Ancient Greek](https://en.wikipedia.org/wiki/Ancient_Greek): βίος (*bios*), life, and μίμησις (*[mīmēsis](https://en.wikipedia.org/wiki/Mimesis" \o "Mimesis)*), imitation, from μιμεῖσθαι (*mīmeisthai*), to imitate, from μῖμος (*mimos*), actor. A closely related field is [**bionics**](https://en.wikipedia.org/wiki/Bionics).[[2]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-McCarty-2)

Living organisms have [evolved](https://en.wikipedia.org/wiki/Evolution) [well-adapted](https://en.wikipedia.org/wiki/Adaptation_(biology)) structures and materials over geological time through [natural selection](https://en.wikipedia.org/wiki/Natural_selection). Biomimetics has given rise to new technologies inspired by [biological](https://en.wikipedia.org/wiki/Biological) solutions at macro and nanoscales. Humans have looked at nature for answers to problems throughout our existence. Nature has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, [hydrophobicity](https://en.wikipedia.org/wiki/Hydrophobicity), self-assembly, and harnessing solar energy.

## Contents

  [[hide](https://en.wikipedia.org/wiki/Biomimetics)]

* [1 Possible applications](https://en.wikipedia.org/wiki/Biomimetics#Possible_applications)
* [2 History](https://en.wikipedia.org/wiki/Biomimetics#History)
* [3 Nanobiomimetics](https://en.wikipedia.org/wiki/Biomimetics#Nanobiomimetics)
  + [3.1 Fabrication](https://en.wikipedia.org/wiki/Biomimetics#Fabrication)
  + [3.2 Biomedicine](https://en.wikipedia.org/wiki/Biomimetics#Biomedicine)
  + [3.3 Nanowires, nanotubes, and quantum dots](https://en.wikipedia.org/wiki/Biomimetics#Nanowires.2C_nanotubes.2C_and_quantum_dots)
  + [3.4 Display technology](https://en.wikipedia.org/wiki/Biomimetics#Display_technology)
* [4 Additional examples](https://en.wikipedia.org/wiki/Biomimetics#Additional_examples)
* [5 See also](https://en.wikipedia.org/wiki/Biomimetics#See_also)
* [6 References](https://en.wikipedia.org/wiki/Biomimetics#References)
* [7 Further reading](https://en.wikipedia.org/wiki/Biomimetics#Further_reading)
* [8 External links](https://en.wikipedia.org/wiki/Biomimetics#External_links)
  + [8.1 Research laboratories](https://en.wikipedia.org/wiki/Biomimetics#Research_laboratories)
  + [8.2 Portals](https://en.wikipedia.org/wiki/Biomimetics#Portals)
  + [8.3 Videos](https://en.wikipedia.org/wiki/Biomimetics#Videos)

## Possible applications[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=1" \o "Edit section: Possible applications)]

[](https://en.wikipedia.org/wiki/File:Leonardo_Design_for_a_Flying_Machine,_c._1488.jpg)Biomimetics could in principle be applied in many fields. Because of the complexity of biological systems, the number of features that might be imitated is large. Some examples of biomimetic applications at various stages of development from prototypes to technologies that might become commercially usable include:[[3]](https://en.wikipedia.org/wiki/Biomimetics" \l "cite_note-3)

[Leonardo da Vinci](https://en.wikipedia.org/wiki/Leonardo_da_Vinci)'s [design for a flying machine](https://en.wikipedia.org/wiki/Science_and_inventions_of_Leonardo_da_Vinci#Flight) with wings based closely upon the structure of bat wings

* Aircraft wing design[[4]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Romei_2008_56-4) and flight techniques[[5]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-5) inspired by birds and bats

[](https://en.wikipedia.org/wiki/File:Stickybot.jpg)

[The Stickybot](https://en.wikipedia.org/wiki/Synthetic_setae)

* Robots based on the physiology and methods of locomotion of animals
  + [BionicKangaroo](https://en.wikipedia.org/wiki/BionicKangaroo) moves like a kangaroo, saving energy from one jump and transferring it to its next jump[[6]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-6)
  + Climbing robots,[[7]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-7) boots and tape[[8]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-8) [mimicking geckos feet and their ability for adhesive reversal](https://en.wikipedia.org/wiki/Synthetic_setae)
* [Nanotechnology surfaces](https://en.wikipedia.org/wiki/Sharklet_(material)) that recreate properties of [shark skin](https://en.wikipedia.org/wiki/Dermal_denticle#Placoid_scales)[[9]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-9)
* Treads on tires[[10]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-10) inspired by the toe pads of [tree frogs](https://en.wikipedia.org/wiki/Tree_frog)
* Self-sharpening teeth found on many animals, copied to make better cutting tools[[11]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-11)
* [Protein folding](https://en.wikipedia.org/wiki/Protein_folding) used to control material formation for [self-assembled functional nanostructures](https://en.wikipedia.org/wiki/Molecular_self-assembly)[[12]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-12)
* The [light refracting properties of butterfly wings](https://en.wikipedia.org/wiki/Structural_coloration) are harnessed to provide [improved digital displays](https://en.wikipedia.org/wiki/Interferometric_modulator_display) and everlasting colour[[13]](https://en.wikipedia.org/wiki/Biomimetics" \l "cite_note-13)
* Better ceramics by copying the properties of seashells[[14]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-14)
* Polar bear fur inspired thermal collectors and clothing[[15]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-15)
* Mimicking the [arrangement of leaves on a plant](https://en.wikipedia.org/wiki/Phyllotaxy) for better solar power collection[[16]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-16)
* Studying the light refractive properties of the moth's eye to produce less reflective solar panels[[17]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-17)
* [Self-healing materials](https://en.wikipedia.org/wiki/Self-healing_material), [polymers](https://en.wikipedia.org/wiki/Polymer) and [composite materials](https://en.wikipedia.org/wiki/Composite_material) capable of mending cracks[[18]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-18)

## History[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=2" \o "Edit section: History)]

One of the early examples of biomimicry was the study of birds to enable human flight. Although never successful in creating a "flying machine", [Leonardo da Vinci](https://en.wikipedia.org/wiki/Leonardo_da_Vinci) (1452–1519) was a keen observer of the anatomy and flight of birds, and made numerous notes and sketches on his observations as well as sketches of "flying machines".[[4]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Romei_2008_56-4) The [Wright Brothers](https://en.wikipedia.org/wiki/Wright_Brothers), who succeeded in flying the first heavier-than-air aircraft in 1903, derived inspiration from observations of pigeons in flight.[[19]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-19)

Biomimetics was coined by the American [biophysicist](https://en.wikipedia.org/wiki/Biophysicist) and [polymath](https://en.wikipedia.org/wiki/Polymath) [Otto Schmitt](https://en.wikipedia.org/wiki/Otto_Schmitt) during the 1950s.[[20]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Vincent2006-20) It was during his doctoral research that he developed the [Schmitt trigger](https://en.wikipedia.org/wiki/Schmitt_trigger) by studying the nerves in squid, attempting to engineer a device that replicated the biological system of [nerve propagation](https://en.wikipedia.org/wiki/Nerve_impulse).[[21]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-21) He continued to focus on devices that mimic natural systems and by 1957 he had perceived a converse to the standard view of biophysics at that time, a view he would come to call biomimetics.[[20]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Vincent2006-20)

Biophysics is not so much a subject matter as it is a point of view. It is an approach to problems of biological science utilizing the theory and technology of the physical sciences. Conversely, biophysics is also a biologist's approach to problems of physical science and engineering, although this aspect has largely been neglected.

—Otto Herbert Schmitt, In Appreciation, A Lifetime of Connections: Otto Herbert Schmitt, 1913 - 1998

A similar term, [*Bionics*](https://en.wikipedia.org/wiki/Bionics) was coined by [Jack Steele](https://en.wikipedia.org/wiki/Jack_Steele) in 1960 at Wright-Patterson Air Force Base in Dayton, Ohio where Otto Schmitt also worked. Steele defined bionics as "the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues".[[2]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-McCarty-2)[[22]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-vincent-2009-22) During a later meeting in 1963 Schmitt stated,

Let us consider what bionics has come to mean operationally and what it or some word like it (I prefer biomimetics) ought to mean in order to make good use of the technical skills of scientists specializing, or rather, I should say, despecializing into this area of research

—Otto Herbert Schmitt, In Appreciation, A Lifetime of Connections: Otto Herbert Schmitt, 1913 - 1998

In 1969 the term biomimetics was used by Schmitt to title one of his papers,[[23]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-23) and by 1974 it had found its way into [Webster's Dictionary](https://en.wikipedia.org/wiki/Webster%27s_Dictionary), bionics entered the same dictionary earlier in 1960 as "a science concerned with the application of data about the functioning of biological systems to the solution of engineering problems". Bionic took on a different connotation when [Martin Caidin](https://en.wikipedia.org/wiki/Martin_Caidin) referenced Jack Steele and his work in the novel *Cyborg* which later resulted in the 1974 television series [*The Six Million Dollar Man*](https://en.wikipedia.org/wiki/The_Six_Million_Dollar_Man) and its spin-offs. The term bionic then became associated with "the use of electronically operated artificial body parts" and "having ordinary human powers increased by or as if by the aid of such devices".[[24]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-24) Because the term *bionic* took on the implication of supernatural strength, the scientific community in [English](https://en.wikipedia.org/wiki/English_language) speaking countries largely abandoned it.[[25]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-25)

The term *biomimicry* appeared as early as 1982.[[26]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-26) Biomimicry was popularized by scientist and author [Janine Benyus](https://en.wikipedia.org/wiki/Janine_Benyus) in her 1997 book *Biomimicry: Innovation Inspired by Nature*. Biomimicry is defined in the book as a "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems". Benyus suggests looking to Nature as a "Model, Measure, and Mentor" and emphasizes sustainability as an objective of biomimicry.[[27]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Benyus_1997-27)

## Nanobiomimetics[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=3" \o "Edit section: Nanobiomimetics)]

### [Electron micrograph of rod shaped TMV particles.](https://en.wikipedia.org/wiki/File:TobaccoMosaicVirus.jpg)Fabrication[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=4" \o "Edit section: Fabrication)]

SEM of rod shaped [tobacco mosaic virus](https://en.wikipedia.org/wiki/Tobacco_mosaic_virus) particles

[Biomorphic mineralization](https://en.wikipedia.org/wiki/Biomineralization) is a technique that produces materials with morphologies and structures resembling those of natural living organisms by using bio-structures as templates for mineralization. Compared to other methods of material production, biomorphic mineralization is facile, environmentally benign and economic.[[28]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Tong-28)

### Biomedicine[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=5" \o "Edit section: Biomedicine)]

Mimicking the diving behavior of animals, researchers have recently discovered that humans have a similar capacity to lower brain temperature and suppress metabolism for neuroprotection.[[29]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Murat-29) This has now opened a real possibility of devising means for humans to sustain this state, not unlike the elusive and enigmatic feat of animal hibernation, e.g., lemurs (primates) and bears. This would have profound biomedical implications for healthcare and for treating an unmatched range and diversity of serious life-threatening clinical conditions, and in a fully personalized way, things like stroke, blood-loss, burns, cancer, chronic obesity, epileptic seizures, etc. An experimental trial, recently conducted in Sweden seemingly resulted in a sustainable variant of this state in a human breath-hold diver.[[30]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-The_Dive_Lab-30)

### Nanowires, nanotubes, and quantum dots[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=6" \o "Edit section: Nanowires, nanotubes, and quantum dots)]

A [virus](https://en.wikipedia.org/wiki/Virus) is a nonliving particle ranging from the size of 20 to 300 nm capsules containing genetic material used to infect its host. The outer layer of viruses are remarkably robust and capable of withstanding temperatures as high as 60 °C and stay stable in a wide range of [pH](https://en.wikipedia.org/wiki/PH) range of 2-10.[[28]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Tong-28) Viral capsids can be used to create several nano device components such as nanowires, nanotubes, and quantum dots. Tubular virus particles such as the [tobacco mosaic virus](https://en.wikipedia.org/wiki/Tobacco_mosaic_virus) (TMV) can be used as templates to create nanofibers and nanotubes since both the inner and outer layers of the virus are charged surfaces and can induce nucleation of crystal growth. This was demonstrated though the production of [platinum](https://en.wikipedia.org/wiki/Platinum) and [gold](https://en.wikipedia.org/wiki/Gold) nanotubes using TMV as a template.[[31]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Dujardin-31) Mineralized virus particles have been shown to withstand various pH values by mineralizing the viruses with different materials such as silicon, [PbS](https://en.wikipedia.org/wiki/Lead(II)_sulfide" \o "Lead(II) sulfide), and [CdS](https://en.wikipedia.org/wiki/Cadmium_sulfide" \o "Cadmium sulfide) and could therefore serve as a useful carriers of material.[[32]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Shenton-32) A spherical plant virus called [cowpea chlorotic mottle virus](https://en.wikipedia.org/wiki/Cowpea_chlorotic_mottle_virus) (CCMV) has interesting expanding properties when exposed to environments of pH higher than 6.5. Above this pH, 60 independent pores with diameters about 2 nm begin to exchange substance with the environment. The structural transition of the viral capsid can be utilized in [Biomorphic mineralization](https://en.wikipedia.org/wiki/Biomineralization) for selective uptake and deposition of minerals by controlling the solution pH. Applications include using the viral cage to produce uniformly shaped and sized quantum dot [semiconductor](https://en.wikipedia.org/wiki/Semiconductor) nanoparticles through a series of pH washes. This is an alternative to the [apoferritin](https://en.wikipedia.org/wiki/Ferritin" \o "Ferritin) cage technique currently used to synthesize uniform CdSe nanoparticles.[[33]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-33) Such materials could also be used for targeted drug delivery since particles release contents upon exposure to specific pH levels.

### Display technology[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=7" \o "Edit section: Display technology)]

[](https://en.wikipedia.org/wiki/File:Morpho_didius_Male_Dos_MHNT.jpg)*Further information:*[*Structural coloration*](https://en.wikipedia.org/wiki/Structural_coloration)*and*[*Patterns in nature*](https://en.wikipedia.org/wiki/Patterns_in_nature)

Vibrant blue color of *[Morpho](https://en.wikipedia.org/wiki/Morpho" \o "Morpho)*butterfly due to [structural coloration](https://en.wikipedia.org/wiki/Structural_coloration).

[Morpho](https://en.wikipedia.org/wiki/Morpho) butterfly wings contain microstructures that create its coloring effect through [structural coloration](https://en.wikipedia.org/wiki/Structural_coloration) rather than [pigmentation](https://en.wikipedia.org/wiki/Pigment). Incident light waves are reflected at specific wavelengths to create vibrant colors due to multilayer interference, diffraction, thin film interference, and scattering properties.[[34]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Ball-34) The scales of these butterflies consist of microstructures such as ridges, cross-ribs, ridge-lamellae, and microribs that have been shown to be responsible for coloration. The structural color has been simply explained as the interference due to alternating layers of cuticle and air using a model of [multilayer interference](https://en.wikipedia.org/wiki/Thin-film_interference). The same principles behind the coloration of [soap bubbles](https://en.wikipedia.org/wiki/Soap_bubble) apply to butterfly wings. The color of butterfly wings is due to multiple instances of constructive [interference](https://en.wikipedia.org/wiki/Interference_(wave_propagation)) from structures such as this. The photonic microstructure of butterfly wings can be replicated through biomorphic mineralization to yield similar properties. The photonic microstructures can be replicated using metal oxides or metal alkoxides such as [titanium sulfate](https://en.wikipedia.org/w/index.php?title=Titanium_sulfate&action=edit&redlink=1) (TiSO4), [zirconium oxide](https://en.wikipedia.org/wiki/Zirconium_oxide) (ZrO2), and [aluminium oxide](https://en.wikipedia.org/wiki/Aluminium_oxide" \o "Aluminium oxide) (Al2O3). An alternative method of vapor-phase oxidation of SiH4 on the template surface was found to preserve delicate structural features of the microstructure.[[35]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-35)

## [https://upload.wikimedia.org/wikipedia/commons/thumb/1/13/Bur_Macro_BlackBg.jpg/220px-Bur_Macro_BlackBg.jpg](https://en.wikipedia.org/wiki/File:Bur_Macro_BlackBg.jpg)Additional examples[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=8" \o "Edit section: Additional examples)]

[Velcro](https://en.wikipedia.org/wiki/Velcro) was inspired by the tiny hooks found on the surface of [burs](https://en.wikipedia.org/wiki/Bur).

Researchers studied the termite's ability to maintain virtually constant temperature and humidity in their termite mounds in Africa despite outside temperatures that vary from 1.5 °C to 40 °C (35 °F to 104 °F). Researchers initially scanned a termite mound and created 3-D images of the mound structure, which revealed construction that can influence human building design. The [Eastgate Centre](https://en.wikipedia.org/wiki/Eastgate_Centre,_Harare" \o "Eastgate Centre, Harare), a mid-rise office complex in [Harare](https://en.wikipedia.org/wiki/Harare), [Zimbabwe](https://en.wikipedia.org/wiki/Zimbabwe),[[36]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-BI-36) stays cool without air conditioning and uses only 10% of the energy of a conventional building its size.

[Janine Benyus](https://en.wikipedia.org/wiki/Janine_Benyus) refers in her books to [spiders](https://en.wikipedia.org/wiki/Spider) that create web silk as strong as the [Kevlar](https://en.wikipedia.org/wiki/Kevlar) used in [bulletproof vests](https://en.wikipedia.org/wiki/Ballistic_vest). Engineers could use such a material—if it had a long enough rate of decay—for parachute lines, suspension bridge cables, artificial ligaments for medicine, and other purposes.[[27]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-Benyus_1997-27)

Other research has proposed adhesive glue from [mussels](https://en.wikipedia.org/wiki/Mussel), solar cells made like leaves, fabric that emulates [shark](https://en.wikipedia.org/wiki/Shark) skin, harvesting water from fog like a [beetle](https://en.wikipedia.org/wiki/Beetle), and more. Nature’s 100 Best is a compilation of the top hundred different innovations of animals, plants, and other organisms that have been researched and studied by the Biomimicry Institute.[[36]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-BI-36)

A display technology based on the reflective properties of certain [morpho](https://en.wikipedia.org/wiki/Morpho" \o "Morpho) [butterflies](https://en.wikipedia.org/wiki/Butterfly) was commercialized by Qualcomm in 2007. The technology uses [Interferometric Modulation](https://en.wikipedia.org/wiki/Interferometric_modulator_display) to reflect light so only the desired color is visible in each individual pixel of the display.

Biomimicry may also provide design methodologies and techniques to optimize engineering products and systems. An example is the re-derivation of [Murray's law](https://en.wikipedia.org/wiki/Murray%27s_law), which in conventional form determined the optimum diameter of blood vessels, to provide simple equations for the pipe or tube diameter which gives a minimum mass engineering system.[[37]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-williams-37)

In structural engineering, the Swiss Federal Institute of Technology ([EPFL](https://en.wikipedia.org/wiki/EPFL)) has incorporated biomimetic characteristics in an adaptive deployable "tensegrity" bridge. The bridge can carry out self-diagnosis and self-repair.[[38]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-korkmaz-38)

The [Bombardier beetle](https://en.wikipedia.org/wiki/Bombardier_beetle)'s powerful repellent spray inspired a Swedish company to develop a "micro mist" spray technology, which is claimed to have a low carbon impact (compared to aerosol sprays). The beetle mixes chemicals and releases its spray via a steerable nozzle at the end of its abdomen, stinging and confusing the victim.[[39]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-39)

[Holistic planned grazing](https://en.wikipedia.org/wiki/Holistic_management), using fencing and/or [herders](https://en.wikipedia.org/wiki/Herder), seeks to restore [grasslands](https://en.wikipedia.org/wiki/Grasslands) by carefully planning movements of large [herds](https://en.wikipedia.org/wiki/Herding_behavior) of livestock to mimic the vast herds found in nature where [grazing](https://en.wikipedia.org/wiki/Grazing) animals are kept concentrated by pack predators and must move on after eating, trampling, and manuring an area, returning only after it has fully recovered. Developed by [Allan Savory](https://en.wikipedia.org/wiki/Allan_Savory),[[40]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-40) this method of biomimetic grazing holds tremendous potential in building soil, increasing biodiversity, reversing desertification, and mitigating global warming,[[41]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-41)[[42]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-42) similar to what occurred during the past 40 million years as the expansion of grass-grazer ecosystems built deep[grassland soils](https://en.wikipedia.org/wiki/Mollisols), sequestering carbon and cooling the planet.[[43]](https://en.wikipedia.org/wiki/Biomimetics#cite_note-43)

## See also[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=9" \o "Edit section: See also)]

|  |  |
| --- | --- |
| [Portal icon](https://en.wikipedia.org/wiki/File:3d_tRNA.png) | [***Biotechnology portal***](https://en.wikipedia.org/wiki/Portal:Biotechnology) |

* [Biomimetic synthesis](https://en.wikipedia.org/wiki/Biomimetic_synthesis)
* [*Bioinspiration & Biomimetics*](https://en.wikipedia.org/wiki/Bioinspiration_%26_Biomimetics)

## References[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=10" \o "Edit section: References)]

* 1. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-1) Vincent, Julian F. V. et al. (22 August 2006).["Biomimetics: its practice and theory"](http://rsif.royalsocietypublishing.org/content/3/9/471).[doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1098/rsif.2006.0127](https://dx.doi.org/10.1098%2Frsif.2006.0127). Retrieved 7 April 2015.
  2. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-McCarty_2-0) [***b***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-McCarty_2-1) Mary McCarty. ["Life of bionics founder a fine adventure"](http://www.daytondailynews.com/o/content/oh/story/opinions/columns/2009/01/29/ddn012909mary.html?cxntlid=inform_sr). *Dayton Daily News*, 29 January 2009.
  3. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-3) Bharat Bhushan (15 March 2009) Biomimetics: lessons from nature–an overview<http://rsta.royalsocietypublishing.org/content/367/1893/1445.full>
  4. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Romei_2008_56_4-0) [***b***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Romei_2008_56_4-1) Romei, Francesca (2008). *Leonardo Da Vinci*. The Oliver Press. p. 56. [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-1-934545-00-3](https://en.wikipedia.org/wiki/Special:BookSources/978-1-934545-00-3).
  5. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-5) ["Drone with legs can perch, watch and walk like a bird"](http://www.newscientist.com/article/dn24951-drone-with-legs-can-perch-watch-and-walk-like-a-bird.html#.U0lxhuZdWcI). *Tech*. New Scientist. 27 January 2014. Retrieved 17 July 2014.
  6. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-6) Ackerman, Evan (2 Apr 2014). ["*Festo's Newest Robot Is a Hopping Bionic Kangaroo*"](http://spectrum.ieee.org/automaton/robotics/robotics-hardware/festo-newest-robot-is-a-hopping-bionic-kangaroo).*spectrum.ieee.org*. [IEEE Spectrum](https://en.wikipedia.org/wiki/IEEE_Spectrum). Retrieved 17 Apr2014.
  7. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-7) [Gecko-like robot scampers up the wall – tech – 23 May 2006 – New Scientist Tech](http://www.newscientisttech.com/channel/tech/mg19025526.500.html)
  8. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-8) ["Gecko Tape"](http://www.stanford.edu/group/mota/education/Physics%2087N%20Final%20Projects/Group%20Gamma/gecko.htm). [Stanford University](https://en.wikipedia.org/wiki/Stanford_University). Retrieved17 July 2014.
  9. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-9) ["'Inspired by Nature'"](http://sharklet.com/technology/). Sharklet Technologies Inc. 2010. Retrieved 6 June 2014.
  10. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-10) [Tire treads inspired by tree frogs](http://iopscience.iop.org/0953-8984/19/37/376110)
  11. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-11) [Wiley: self-sharpening teeth](http://onlinelibrary.wiley.com/doi/10.1002/adfm.201001546/abstract;jsessionid=E2E9980D17B063A5D9F5B2CFE4EDD85D.d02t01)
  12. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-12) [Self-assembled nanostructures](http://www.jnanobiotechnology.com/content/12/1/4)
  13. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-13) [IOP Science: structurally colored displays](http://iopscience.iop.org/1468-6996/12/6/064709)
  14. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-14)<http://onlinelibrary.wiley.com/doi/10.1002/adma.201202079/abstract%7CYao>, Y., Wang, Q., Wang, H., Zhang, B., Zhao, C., Wang, Z., Xu, Z., Wu, Y., Huang, W., Qian, P.-Y. and Zhang, X. X. (2013), Bio-Assembled Nanocomposites in Conch Shells Exhibit Giant Electret Hysteresis. Adv. Mater., 25: 711–718. doi: 10.1002/adma.201202079
  15. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-15)<http://rsta.royalsocietypublishing.org/content/367/1894/1749%7CBionics>in textiles: flexible and translucent thermal insulations for solar thermal applications|Published 29 March 2009 doi: 10.1098/rsta.2009.0019 Phil. Trans. R. Soc. A 13 May 2009 vol. 367 no. 1894 1749-1758
  16. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-16) ["The Secret of the Fibonacci Sequence in Trees"](http://www.amnh.org/learn-teach/young-naturalist-awards/winning-essays2/2011-winning-essays/the-secret-of-the-fibonacci-sequence-in-trees).*2011 Winning Essays*. [American Museum of Natural History](https://en.wikipedia.org/wiki/American_Museum_of_Natural_History). 1 May 2014. Retrieved 17 July 2014.
  17. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-17) Wilson, S.J. Wilson; Hutley, M.C. (1982). "The Optical Properties of 'Moth Eye' Antireflection Surfaces". *Journal of Modern Optics* **29** (7): 993–1009.
  18. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-18) Zang, M.Q. (2008). "Self healing in polymers and polymer composites. Concepts, realization and outlook: A review". *Polymer Letters* **2** (4): 238–250.[doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.3144/expresspolymlett.2008.29](https://dx.doi.org/10.3144%2Fexpresspolymlett.2008.29).
  19. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-19) Howard, Fred (1998). *Wilbur and Orville: A Biography of the Wright Brothers*. Dober Publications. p. 33. [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-0-486-40297-0](https://en.wikipedia.org/wiki/Special:BookSources/978-0-486-40297-0).
  20. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Vincent2006_20-0) [***b***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Vincent2006_20-1) Vincent, Julian F.V.; Bogatyreva, Olga A., Bogatyrev, Nikolaj R., Bowyer, Adrian, Pahl, Anja-Karina (21 August 2006). "Biomimetics: its practice and theory". *Journal of The Royal Society Interface* **3**(9): 471–482. [doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1098/rsif.2006.0127](https://dx.doi.org/10.1098%2Frsif.2006.0127).
  21. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-21) ["Otto H. Schmitt, Como People of the Past"](https://sites.google.com/a/comogreenvillage.info/como-history/home/people-of-the-past-documents/como-people-of-the-past/otto-h-schmitt). Connie Sullivan, Como History Article.
  22. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-vincent-2009_22-0) Vincent, Julian F. V. (November 2009). "Biomimetics -- a review". *Journal of Engineering in Medicine*. Proceedings of the Institution of Mechanical Engineers. Part H **223** (8): 919–939.[doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1243/09544119JEIM561](https://dx.doi.org/10.1243%2F09544119JEIM561).
  23. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-23) Schmitt O. Third Int. Biophysics Congress. 1969. Some interesting and useful biomimetic transforms. p. 297.
  24. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-24) *Compact Oxford English Dictionary*. 2008.[ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number" \o "International Standard Book Number) [978-0-19-953296-4](https://en.wikipedia.org/wiki/Special:BookSources/978-0-19-953296-4).
  25. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-25) Vincent, JFV (2009). "Biomimetics — a review".*Proc. I. Mech. E.* **223**: p919–939.
  26. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-26) Merrill, Connie Lange (1982). "Biomimicry of the Dioxygen Active Site in the Copper Proteins Hemocyanin and Cytochrome Oxidase". Rice University.
  27. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Benyus_1997_27-0) [***b***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Benyus_1997_27-1) Benyus, Janine (1997). *Biomimicry: Innovation Inspired by Nature*. New York, USA: [William Morrow & Company](https://en.wikipedia.org/wiki/William_Morrow_%26_Company). [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [978-0-688-16099-9](https://en.wikipedia.org/wiki/Special:BookSources/978-0-688-16099-9).
  28. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Tong_28-0) [***b***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Tong_28-1) Tong-Xiang, Suk-Kwun, Di Zhang. "Biomorphic Mineralization: From biology to materials." State Key Lab of Metal Matrix Composites. Shanghai: Shanghai Jiaotong University , n.d. 545-1000.
  29. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Murat_29-0) Murat, S. "J. Appl. Physiol." 2013. 110:(2): 573-574.
  30. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-The_Dive_Lab_30-0) ["Life-science start-up focused on bringing"](http://www.thedivelab.com/hibernaut-milestones-1.html). The Dive Lab. Retrieved 17 July 2014.
  31. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Dujardin_31-0) Dujardin E., Peet C. "Nano Lett." 2003. 3:413.
  32. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Shenton_32-0) Shenton W. Douglas, Young M. "Adv. Materials." 1999. 11:253.
  33. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-33) Ischiro Yamashita, Junko Hayashi, Mashahiko Hara. "Bio-template Synthesis of Uniform CdSe Nanoparticles Using Cage-shaped Protein, Apoferritin." Chemistry Letters (2004). Volume: 33, Issue: 9. 1158–1159.
  34. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-Ball_34-0) Ball, Philip (May 2012). ["Scientific American"](http://www.nature.com/scientificamerican/journal/v306/n5/full/scientificamerican0512-74.html).*Nature's Color Tricks* **306**. pp. 74–79.[doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1038/scientificamerican0512-74](https://dx.doi.org/10.1038%2Fscientificamerican0512-74). Retrieved3 June 2012.
  35. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-35) Cook G., Timms P.L., Goltner-Spickermann C. Angew. "Chem Int Ed." 2003. 42:557.
  36. ^ [Jump up to:***a***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-BI_36-0) [***b***](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-BI_36-1) [Biomimicry Examples — Biomimicry Institute](http://biomimicry.org/biomimicry-examples#architecture)
  37. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-williams_37-0) Williams, Hugo R.; Trask, Richard S., Weaver, Paul M. and Bond, Ian P. (2008). ["Minimum mass vascular networks in multifunctional materials"](http://rsif.royalsocietypublishing.org/content/5/18/55.full). *Journal of the Royal Society Interface* **5** (18): 55–65.[doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1098/rsif.2007.1022](https://dx.doi.org/10.1098%2Frsif.2007.1022). [PMC](https://en.wikipedia.org/wiki/PubMed_Central) [2605499](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2605499).[PMID](https://en.wikipedia.org/wiki/PubMed_Identifier) [17426011](https://www.ncbi.nlm.nih.gov/pubmed/17426011).
  38. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-korkmaz_38-0) Korkmaz, Sinan; Bel Hadj Ali, Nizar, Smith, Ian F.C. (2011). ["Determining Control Strategies for Damage Tolerance of an Active Tensegrity Structure"](http://infoscience.epfl.ch/record/164609/files/Korkmaz%20et%20al,%20Determining%20Control%20Strategies%20for%20Damage%20Tolerance%20of%20an%20Active%20Tensegrity%20Structure,%20Engineering%20Structures%20(2011)_2.pdf) (PDF).*Engineering Structures* **33** (6): 1930–1939.[doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1016/j.engstruct.2011.02.031](https://dx.doi.org/10.1016%2Fj.engstruct.2011.02.031).
  39. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-39) [Swedish Biomimetics: The μMist Platform Technology](http://www.swedishbiomimetics.com/biomimetics_folder.pdf). Retrieved 3 June 2012.
  40. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-40) Savory, Allan; Jody Butterfield (1998-12-01) [1988]. Holistic Management: A New Framework for Decision Making (2nd ed. ed.). Washington, D.C.: Island Press.[ISBN 1-55963-487-1](https://en.wikipedia.org/wiki/Special:BookSources/1559634871).
  41. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-41) ["Allan Savory: How to green the desert and reverse climate change."](http://www.ted.com/talks/allan_savory_how_to_green_the_world_s_deserts_and_reverse_climate_change.html) TED Talk, February 2013.
  42. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-42) Thackara, John (June 2010). ["Greener Pastures"](http://seedmagazine.com/content/article/Greener_Pastures).*Seed Magazine*.
  43. [**Jump up^**](https://en.wikipedia.org/wiki/Biomimetics#cite_ref-43) Retallack, Gregory (2001). ["Cenozoic Expansion of Grasslands and Climatic Cooling"](http://blogs.uoregon.edu/gregr/files/2013/07/grasslandscooling-nhslkh.pdf) (PDF). [*The Journal of Geology*](https://en.wikipedia.org/wiki/The_Journal_of_Geology) (University of Chicago Press) **109**: 407–426. [doi](https://en.wikipedia.org/wiki/Digital_object_identifier):[10.1086/320791](https://dx.doi.org/10.1086%2F320791).

## Further reading[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=11" \o "Edit section: Further reading)]

* [Thompson, D'Arcy W.](https://en.wikipedia.org/wiki/D%27Arcy_Wentworth_Thompson), *On Growth and Form*. Dover 1992 reprint of 1942 2nd ed. (1st ed., 1917).
* [Vogel, S.](https://en.wikipedia.org/wiki/Steven_Vogel), *Cats' Paws and Catapults: Mechanical Worlds of Nature and People*. Norton & co. 2000.
* Benyus, J. M. (2001). *Along Came a Spider*. Sierra, 86(4), 46-47.
* Hargroves, K. D. & Smith, M. H. (2006). *Innovation inspired by nature Biomimicry*. Ecos, (129), 27-28.
* Marshall, A. (2009). *Wild Design: The Ecomimicry Project*, North Atlantic Books: Berkeley.
* Pyper, W. (2006). *Emulating nature: The rise of industrial ecology*. Ecos, (129), 22-26.
* Smith, J. (2007). *It’s only natural*. The Ecologist, 37(8), 52-55.
* Passino, Kevin M. (2004). *Biomimicry for Optimization, Control, and Automation.* Springer.

## External links[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=12" \o "Edit section: External links)]

### Research laboratories[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=13" \o "Edit section: Research laboratories)]

* [University of Auckland](http://www.abi.auckland.ac.nz/uoa/home/about/our-research/projects/biomimetics)
* [University of Bath](http://www.bath.ac.uk/mech-eng/biomimetics/)
* [Biomimicry Institute](http://www.biomimicry.org/)
* [European Space Agency](http://www.esa.int/gsp/ACT/bio/index.htm)
* [Harvard University Wyss Institute](http://wyss.harvard.edu/viewpage/100/biomimetic-microsystems)
* [MIT](http://biomimetics.mit.edu:8100/wordpress/)
* [University of Reading](http://www.reading.ac.uk/biomim/home.htm)
* [University of Southern California](http://bmes-erc.usc.edu/)
* [Stanford University](http://www-cdr.stanford.edu/biomimetics/)
* [University of Toronto](http://www.mie.utoronto.ca/labs/bidlab/)
* [Tufts University](http://ase.tufts.edu/bdl/default.asp)
* [Virginia Tech](http://www.esm.vt.edu/~staplesa/)
* [University of Washington](http://depts.washington.edu/bionano2/)
* [Biorobotics research group](http://www.biorobotics.eu/), [Institute of Movement Science, CNRS/Aix-Marseille University](http://www.ism.univ-amu.fr/?lang=en) (France)

### Portals[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=14" \o "Edit section: Portals)]

* [Ask Nature - Biomimicry Design Portal](http://www.asknature.org/)

### Videos[[edit](https://en.wikipedia.org/w/index.php?title=Biomimetics&action=edit&section=15)]

* [Biomimetics MIT](http://www.youtube.com/user/MITbiomimetics)
* [*Sex, Velcro and Biomimicry* with Janine Benyus](http://www.scribemedia.org/2008/10/22/float-like-a-butterfly-with-janine-benyus)
* [Janine Benyus: Biomimicry in Action](http://www.ted.com/talks/janine_benyus_biomimicry_in_action.html) from TED 2009
* [Design by Nature - National Geographic](http://ngm.nationalgeographic.com/2008/04/biomimetics/clark-photography)
* [Michael Pawlyn: Using nature's genius in architecture](http://www.ted.com/talks/michael_pawlyn_using_nature_s_genius_in_architecture.html) from TED 2010
* [Robert Full shows how human engineers can learn from animals' tricks](http://www.ted.com/talks/robert_full_on_engineering_and_evolution.html) from TED 2002
* [*The Fast Draw: Biomimicry*](http://www.eveningnews.com/blogs/2009/11/08/fastdraw/entry5577007.shtml) from CBS Newsou